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F. DELLECHAIE, VICE PRESIDENT - EXPLORATION

COLLECTION AND COLLATION OF GEOCHEMICAL AND HYDROLOGICAL PARAMETERS OF GEOTHERMAL SYSTEMS IN COLORADO AND AN EVALUATION OF GEOTHERMAL RESERVOIR TEMPERATURES - A PRELIMINARY APPRAISAL

by

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The Colorado Geological Survey, in conjunction with the U. S. Geological Survey began (May 1975) a two-year evaluation of the geothermal resources of Colorado utilizing hydrogeological and geochemical data and geothermometer models. This investigation, sponsored by the U. S. Geological Survey as a part of its Geothermal Research Program, is being funded in part by Grant No. 14-08-0001-6-221.

The Buena Vista Thermal area encompasses all of Mt. Princeton which is located approximately ten miles (16 kilometers) southwest of Buena Vista, Colorado in the Upper Arkansas Valley. Two hot spring groups occur in this thermal area: Mt. Princeton Hot Spring Group on the south and Cottonwood Hot Spring Group on the north flank of Mt. Princeton.

Revised reservoir temperature estimates based on the SiO_2, Na-K, and Na-K-Ca geothermometers are as follows: 97°C - 110°C, 131°C-141°C, 68°C - 85°C, respectively at the Cottonwood Hot Springs Group and 103°C - 120°C, 135°C - 156°C, 60°C - 97°C, respectively at the Mt. Princeton Hot Springs Group. Mixing model studies yield temperature estimates from 168°C - 232°C (model #1), and 131°C - 150°C (model #2) with cold water fractions from 52% to 80% of the spring flow. The mechanics of calculating subsurface temperatures and the assumptions involved in the use of geothermometers were discussed previously in the first semi-annual technical report.

During the computation of subsurface temperature estimates for the thermal springs and wells in Colorado it became apparent that variation in these estimates occured when the assumptions implicit in the models were violated. The magnitude of variation depends upon the sensitivity of the geothermometer model to various parameters. Figures 1 through 5 illustrate model sensitivity to changes in the analyzed or assumed mineral content of the thermal fluids versus the actual equilibrated water composition at depth.

The sensitivity of the Na-K-Ca geothermometer model to variation of the sodium, potassium or calcium ion content is illustrated in figure 1. Fluctuation of the ion concentration may be due to several factors including dilution of the ascending thermal fluids by cooler groundwaters or contribution of sodium, potassium and calcium ions from minerals other than albite, muscovite, orthoclase and anorthite. The Na-K-Ca geothermometer sensitivity is inversely proportional to the total dissolved solids content of the thermal spring; high T. D. S. springs are less sensitive, low T. D. S. springs are more sensitive to change in the sodium, potassium or calcium ion concentration. This model is much more sensitive to fluctuations in the potassium concentration than a corresponding change in the sodium or calcium content regardless of the total dissolved solids content.

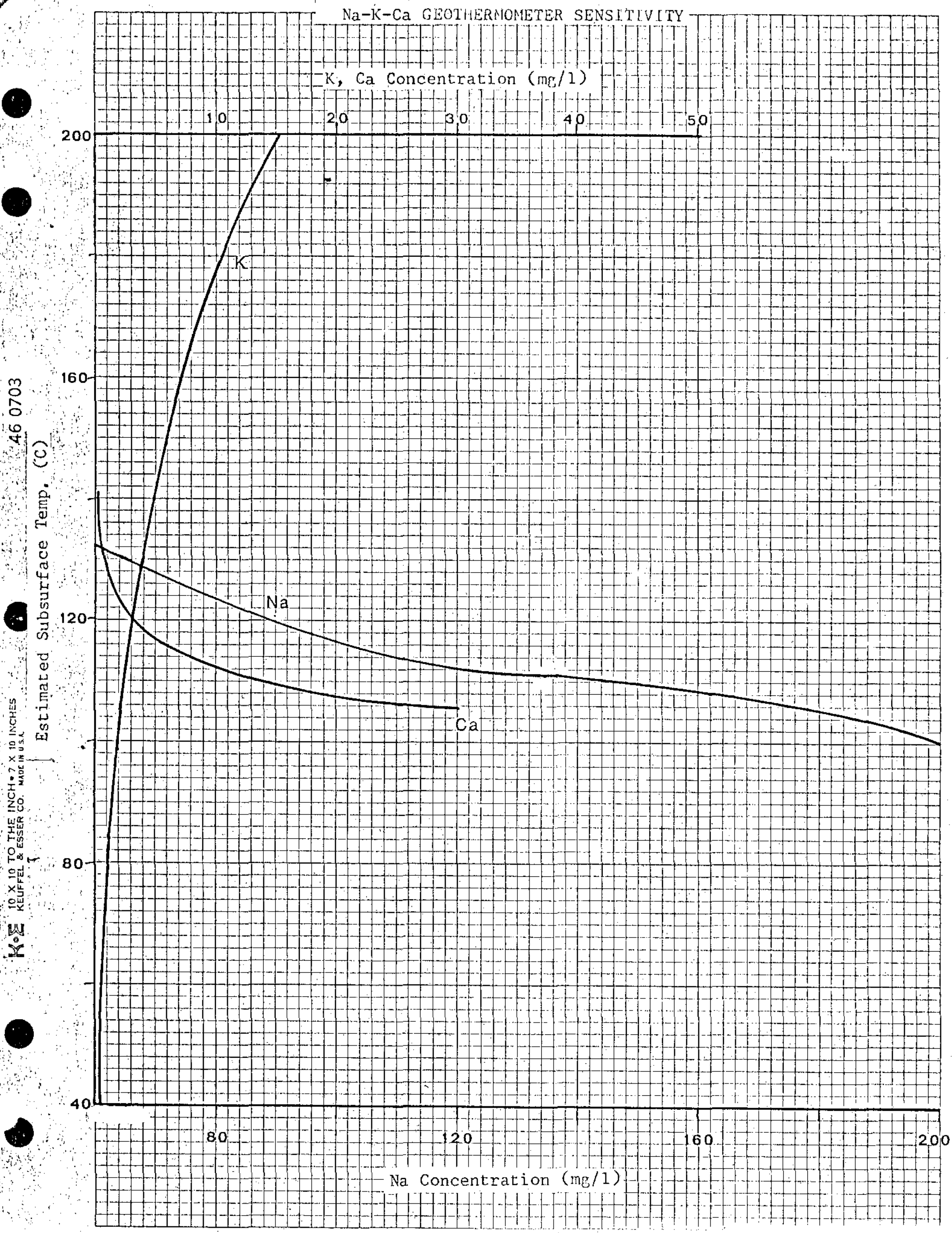
Mixing models require the investigator to assume the temperature and silica content of the cold ground waters that have mixed with the ascending thermal fluids. Figures 2 and 3 illustrate the sensitivity of Mixing Models I and II to the assumed temperature and silica content of the cold water fraction of the thermal spring. An assumed cold water temperature in excess of the actual conditions results in reservoir temperature estimates that are too high. If the assumed silica content of the cold water is in excess of the actual concentration then the reservoir temperature estimate will be too low. These relationships also apply to Mixing Model II (figures 2 and 3), however Mixing Model II is less sensitive to variation in assumed temperature and silica content than Mixing Model I. The sensitivity of both mixing models is inversely proportional to the temperature and/or silica content of the thermal spring; they are less sensitive when applied to high temperature, high silica content springs, they are more sensitive when applied to low temperature, low silica content thermal springs.

Truesdell and Fournier recently (1975) proposed a new geothermometer model to calculate the subsurface temperature of mixed springs that issue at the boiling point. This method assumes that 1) an unmixed water sample is available; 2) no heat loss or gain occurs before or after mixing; 3) quarty reequilibration occurs after mixing; 4) silica is not precipitated during ascent of the mixed water to the surface. Violation of assumptions 1, 2, and 4 results in a minimum estimate, violation of assumption 3 results in an excessive estimate of subsurface temperature.

Hortense Hot Spring (Mt. Princeton Hot Spring Group) issues at 83°C which is near the boiling point at the surface (elevation 8300', 2530 meters). Fournier's graphical method of calculating the subsurface temperature with the enthalpy - chloride geothermometer is illustrated in figure 4. The resulting temperature estimate ranges from 124° to 193°C due to wide variation of the cold water fraction in the thermal springs. The "best fit" of this data suggests subsurface temperatures of 145°C.

A plot of the field data (temperature and silica content) of springs in the Mt. Princeton Group compared to the silica geothermometer (figure 5) yields subsurface temperature estimates of 145°C and 150°C (adiabatic and conductive cooling, respectively). Since this estimate is within 30°C of the enthalpy - chloride model estimate it is likely that this represents the actual subsurface temperature, (J. Pearson, personal communication).

Figure 1



Na-K-Ca GEOTHERMOMETER SENSITIVITY
K, Ca Concentration (mg/l)
10
20
30
40
50
200
160
120
80
40
Estimated Subsurface Temp. (C)
K
Na
Ca
80
120
160
200
Na Concentration (mg/l)
K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 0703

Figure 2

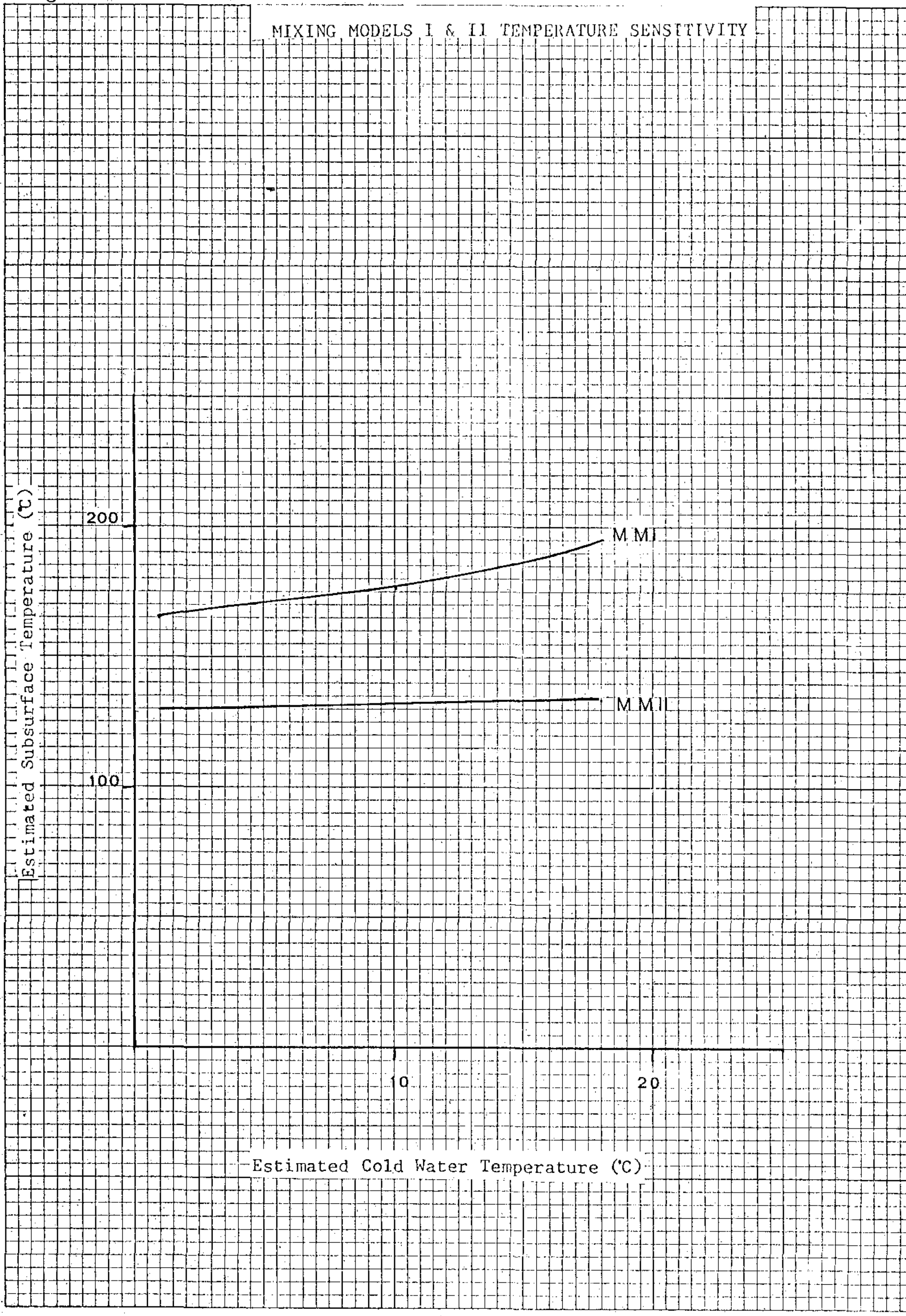

MIXING MODELS I & II TEMPERATURE SENSITIVITY
Estimated Subsurface Temperature (°C)
200
100
MMI
MMII
10
20
Estimated Cold Water Temperature (°C)

Figure 3

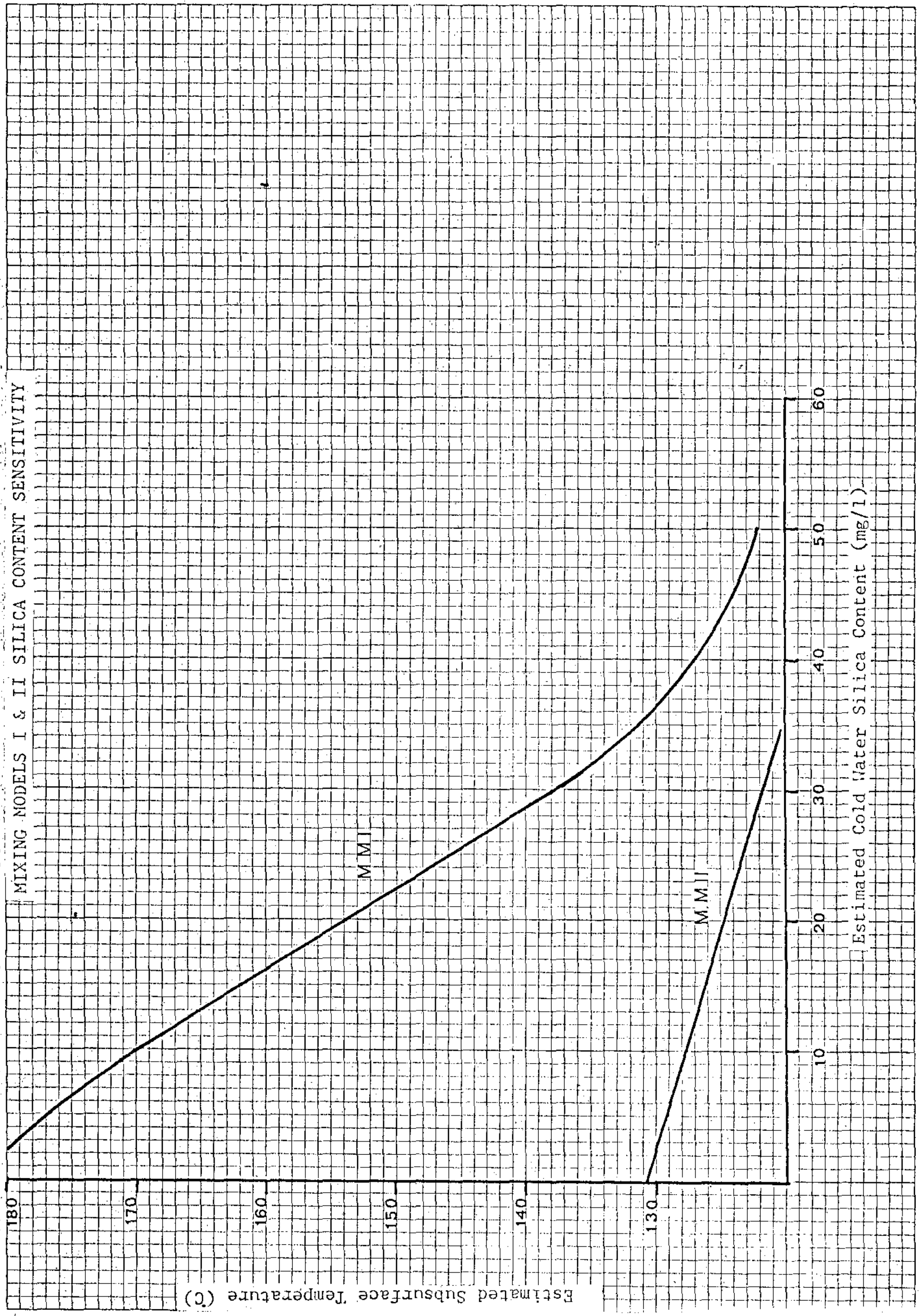

MIXING MODELS I & II SILICA CONTENT SENSITIVITY
MM I
MM II
Estimated Cold Water Silica Content (mg/l)
10
20
30
40
50
60
Estimated Subsurface Temperature (C)
180
170
160
150
140
130

Figure 4

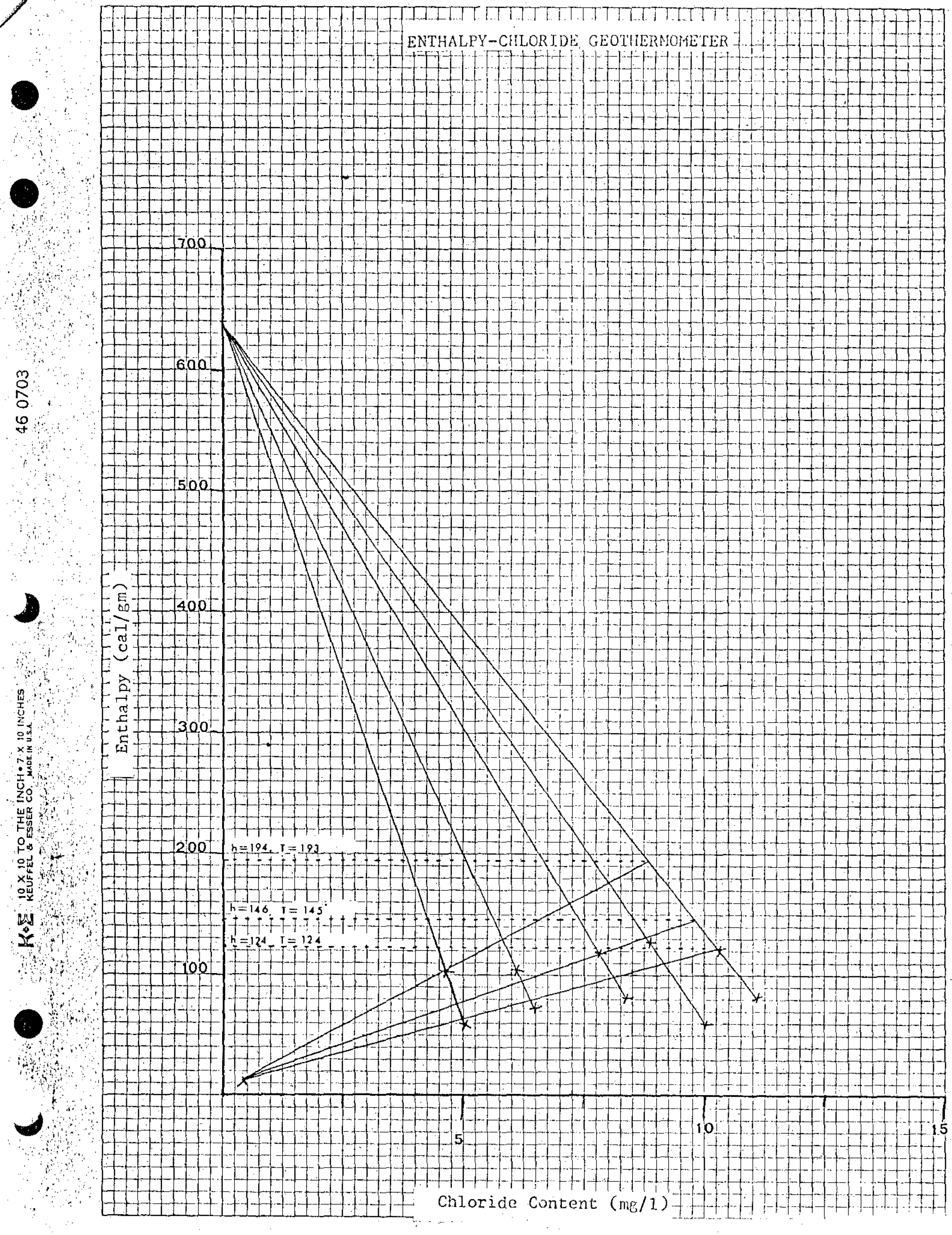

ENTHALPY-CHLORIDE GEOTHERMOMETER
700
600
500
400
300
200
100
Enthalpy (cal/gm)
h=194, T=193
h=146, T=145
h=124, T=124
5
10
15
Chloride Content (mg/l)
46 0703
K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
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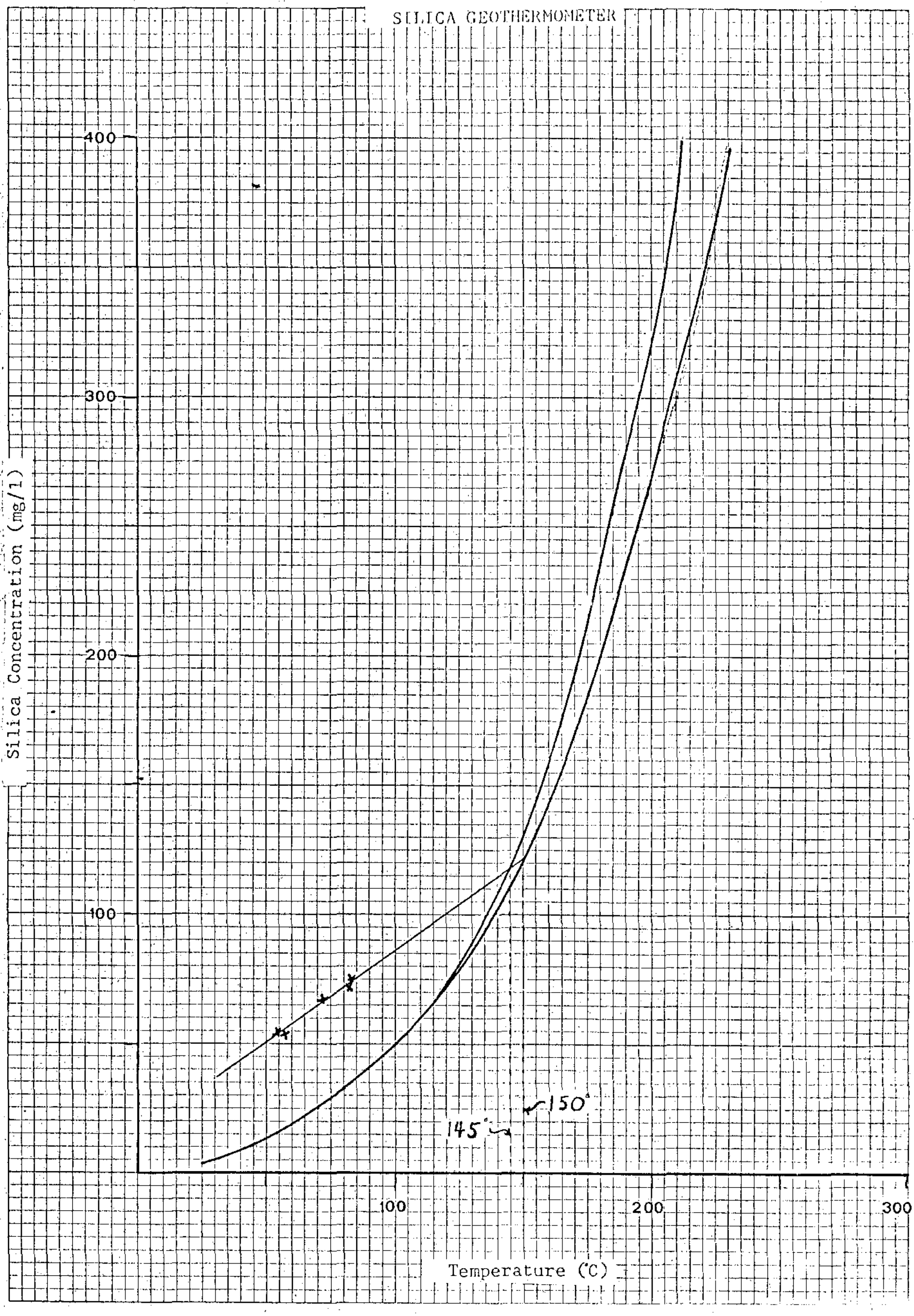
Figure 5



SILICA GEOTHERMOMETER
Silica Concentration (mg/1)
400
300
200
100
100
200
300
Temperature (°C)
145°
150°